Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2342719 A1 2002/05/20

(21) 2 342 719

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(22) Date de dépôt/Filing Date: 2001/04/02

(41) Mise à la disp. pub./Open to Public Insp.: 2002/05/20

(30) Priorité/Priority: 2000/11/20 (2,326,362) CA

(51) Cl.Int.[7]/Int.Cl.[7] G02B 26/00, H04J 14/02, H04J 14/00

(71) Demandeur/Applicant:
JDS UNIPHASE INC., CA

(72) Inventeurs/Inventors:
MACDONALD, ROBERT I., CA;
DUCELLIER, THOMAS, CA;
IYER, RAJIV, CA

(74) Agent: TEITELBAUM, NEIL

(54) Titre : DEMULTIPLEUR EN LONGUEUR D'ONDE ATOM/EGALISEUR DE CANAL DYNAMIQUE/EGALISEUR DE GAIN DYNAMIQUE/BLOQUEUR DE CANAL/MODULE D'INSERTION-EXTRACTION OPTIQUE CONFIGURABLE/COMMUTATION EN LONGUEUR D'ONDE

(54) Title: WAVELENGTH ATOM - DEMUX/DYNAMIC CHANNEL EQUALIZER/DYNAMIC GAIN EQUALIZER/CHANNEL BLOCKER/CONFIGURABLE OPTICAL ADD-DROP MODULE/WAVELENGTH SWITCHING

JDS Uniphase Inc.

Preliminary
DISCLOSURE OF INVENTION

Disclosure Number DI 105
Date Received
Received by:
Patent Committee Use

A. Administrative:
Title of Invention

Wavelength ATOM - Demux/Dynamic Channel Equalizer/Dynamic Gain Equalizer/Channel Blocker/Configurable Optical Add-Drop Module/Wavelength Switching

Inventor(s):

Name	*Signature*	*Identify Inventive Contribution*
Rajiv Iyer		Thought of the many variants of the LargeScale OXC switch to include wavelength manipulation • Demux (not flat top) • Demux (flat top) • Demuxed DCE (not flat top) • Demuxed DCE (flat top) • Demuxed COADM (not flat top) • Demuxed COADM (flat top) • Muxed DCE / DGE / Channel Blocker (flat top) • Muxed COADM (flat top) • Multi-fiber Demux (flat top) • Demuxed Wavelength Switch • Muxed Wavelength Switch (with Thomas Ducellier)
Thomas Ducellier		• Muxed Wavelength Switch (with Rajiv Iyer) • Proposed modification of the Muxed DCE to DGE • Proposed modification to Demuxed COADM (flat top) to perform added functionality of wavelength switching
Ian MacDonald		• Muxed Wavelength Channel Blocker with Polarization Diversity Sagnac device and TIR MEMS channel shifter

B. Has any publication or disclosure to others been made?

No

C. Description
Answer all the following.
a) In one sentence, what is the invention?

These ideas follow from the latest version of the Large Scale OXC as proposed by Thomas Ducellier. In one of the (semi) focal planes of the ATO lens (or mirror), instead of placing a MEMS optical tilting mirror, it proposed here that a dispersive grating be placed such that each wavelength channel is angularly dispersed. After being relayed through the ATO lens (or mirror), MEMS micro-mirrors can be used to perform wavelength functionality such as Demux, Dynamic

Channel Equalization (DCE), Dynamic Gain Equalizer (DGE), COADM functionality or wavelength switching.

b) DESCRIBE THE INVENTION IN DETAIL. Completeness is essential. Note that the description given may be filed directly without editing in order to establish priority.Use extra sheets as necessary. The disclosure should be understandable by a non- specialist technical person. Diagrams are usually necessary to explain an invention adequately.

As proposed in an earlier invention, to take full advantage of the scaling rules that define the compact large scale OXC in the In-Line configuration, we use an Angles to Offsets lens (ATO lens) whereby the beam size at the front focal plane is equal to the beam size at the rear focal plane. As well, any angular deviations in one of these planes in converted to offsets in the other. Switching is done where a MEMS array of tilting mirrors is placed at these planes. It should be noted that a hole is placed in the centre of each MEMS chip to pass the aggregate light from the input, and to the output relay lenses.

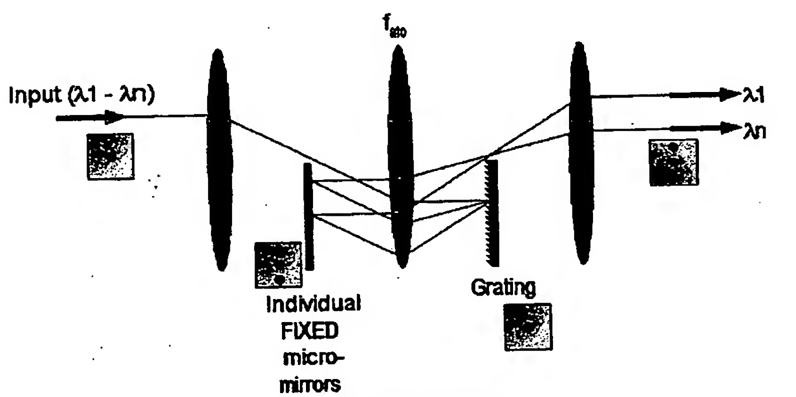
This disclosure of invention describes the use of a dispersive grating in either one or both focal planes of the ATO lens, providing a compact design for many devices. It should also be noted, that in some of the embodiments shown below, it is seen that it is not necessarily necessary that the beam size on either side of the ATO lens be of the same size. Note however that the Angles to Offsets transformation is still being done, and therefore, the ATO nomenclature will still be used.

Please note that in the embodiments below, it is probable that each input be outfitted with polarization diversity, where each input beam is split spatially into 2 sub-beams and where the polarization of one (or both) of the sub-beams is rotated such that both sub-beams propagate through the system and hit the grating with the same polarization. This is to ensure low PDL.

It should also be noted that the lens in the embodiments described below could be a reflective curved mirror where the front and back focal lengths co-incide.

Demultiplexer (not Flat-Top)

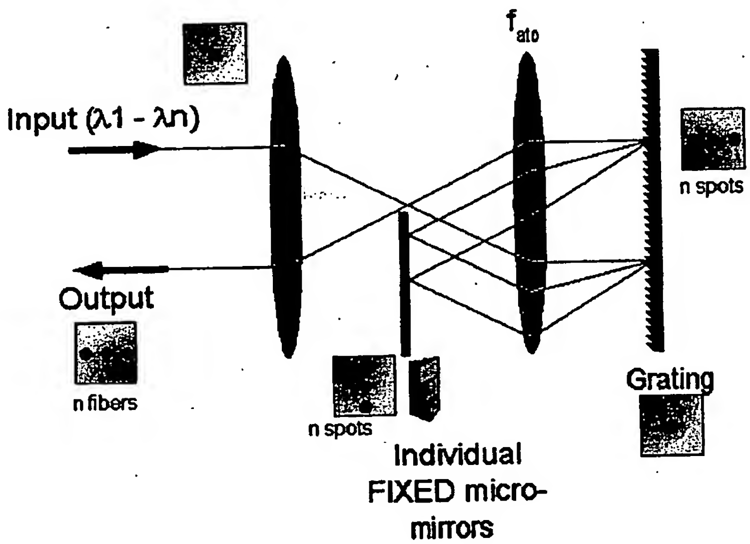
Presented below is a simple modification of the In-Line ATOM, where only one input fiber containing muxed wavelength channels is used, and where a grating has been placed in the "back" focal plane of the ATO lens. We see that the angular dispersion at the grating results in each wavelength channel hitting individual FIXED micro-mirrors which correct the angular orientation of the individual beams so that they proceed to the output fibers. Note that the mirror array need not be MEMS (i.e. it need not be a moving mechanical device).
Note that in this system, it is necessary that the beam (or mode) size on either side of the ATO lens be the same.
Note too that this Demux is not flat top, since the dispersion per channel is not compensated for.



Demux (not Flat-Top)

Demultiplexer (Flat-Top)

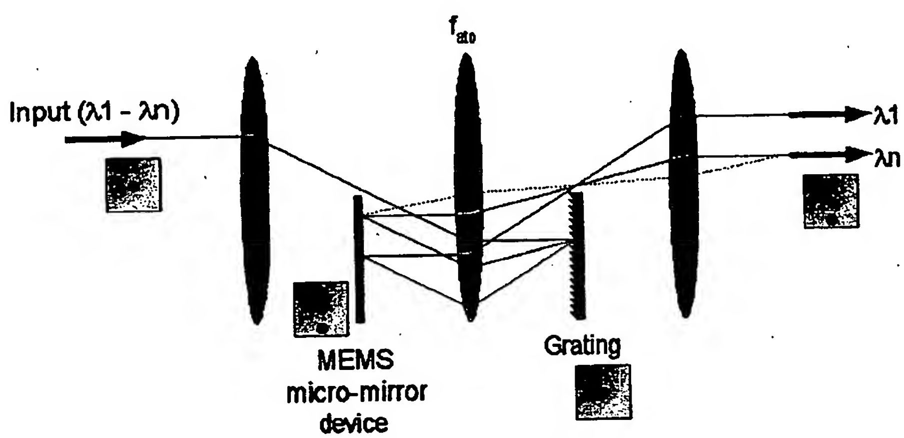
In order to achieve flat top performance on each channel, we need to introduce negative dispersion by hitting the grating a second time. Note the use of the FIXED mirror array which tilts each wavelength horizontally to a different horizontal position. Also note that if Littrow or similar placement of the gratings is desired, then two separate gratings may be used instead of the one grating shown.



Demux (Flat-Top)

Demuxed Dynamic Channel Equalizer (DCE) (not Flat-Top)

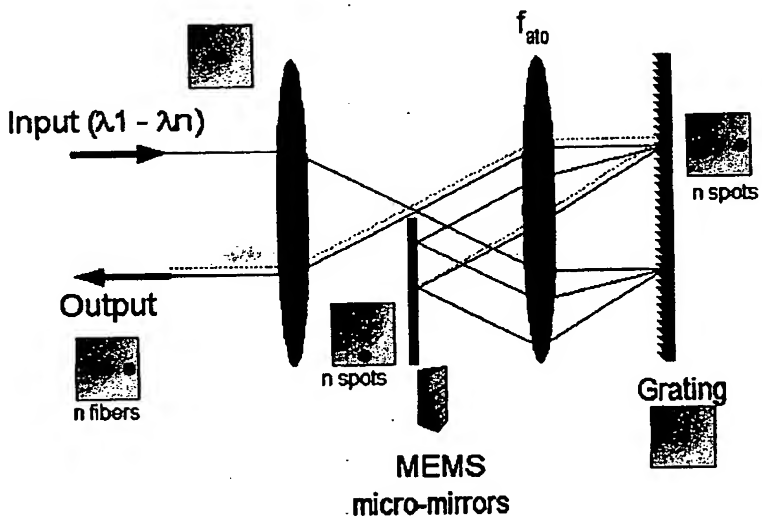
In a simple variant to the above demux, the fixed-micro-mirror linear array is replaced with a MEMS device where each micro-mirror induces a certain tilt such that by the time the beams hit their respective output fiber, they are tilted, thereby inducing loss on a per channel basis. Note that the proposed MEMS device is analog (meaning there is a monotonically increasing loss versus angular tilt relationship).
Note that this is not a flat top design.



Demuxed DCE (not Flat-Top)

Demuxed DCE (Flat-Top)

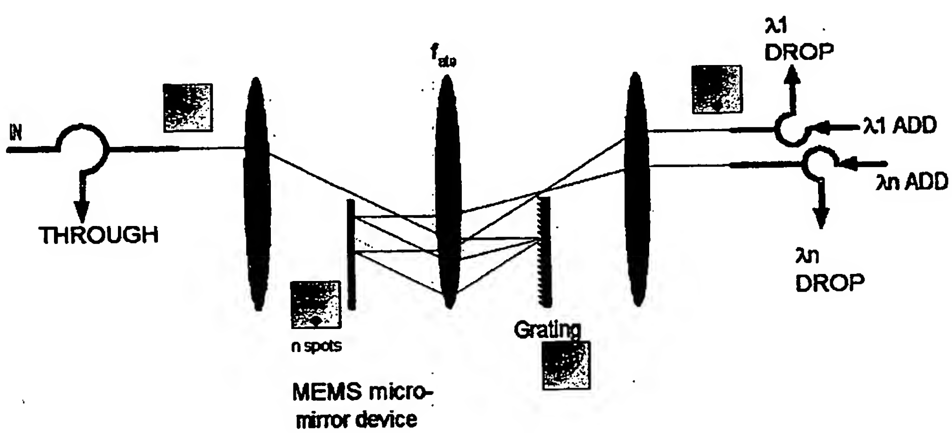
The flat-top demux shown earlier can be modified to perform a demuxed DCE where the fixed micro mirrors are replaced by MEMS, where the tilt causes the beam to walk off the output pickup fiber.



Demuxed DCE (Flat-Top)

Demuxed COADM (not Flat-Top)

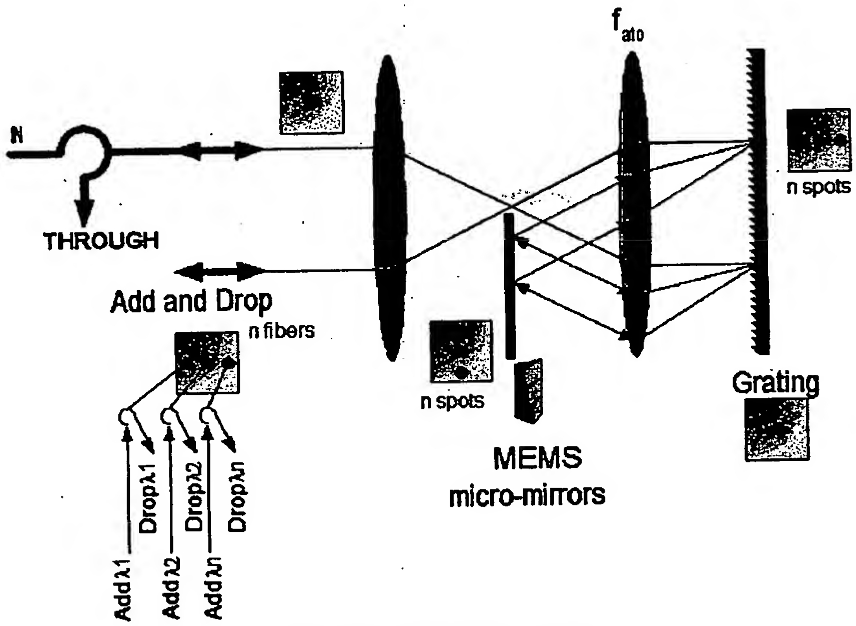
In a simple variant to the above Demuxed DCE, the input fiber and the array of wavelength demuxed output fibers are outfitted with circulators. As well, the MEMS micro-mirror device is bistable. In the mirror's first position, the beam is retro-reflected along its incoming path (originally from the 'In' port) and sent out the 'Through' port. In the mirror's second position, the beam angle is reflected to be parallel to the optical axis and sent out to the demuxed output channels via the 'Drop' port. With the mirrors located for a drop, one may now send light via the 'Add' ports to be routed out via the 'Through' port. Note that DCE functionality is also possible if desired.
Note that this is not a flat top design



Demuxed COADM (not Flat-Top)

Demuxed COADM (Flat-Top)

In a simple variant to the Flat-Top Demuxed DCE shown earlier, the MEMS chip used for this embodiment is bistable. The first position reflects the light back down it's original path and out the 'Through' port. The other position tilts each wavelength the same angle in the vertical direction and a different angle in the horizontal direction. (See Flat-Top Demux for details). Note that once again, each output requires a circulator for 'Add' and 'Drop'.

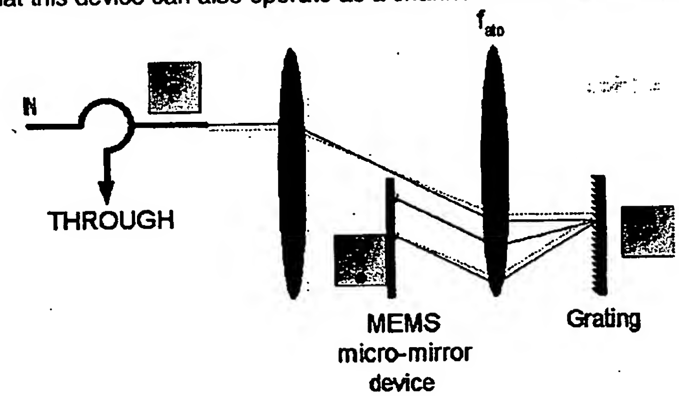


Demuxed COADM (Flat-Top)

Note the added advantage introduced by modifying the single-axis motion of the micro-mirrors. By adding horizontal tilt as well, wavelength switching can be done as well as the COADM functionality.

Muxed DCE / DGE / Channel Blocker (Flat-Top)

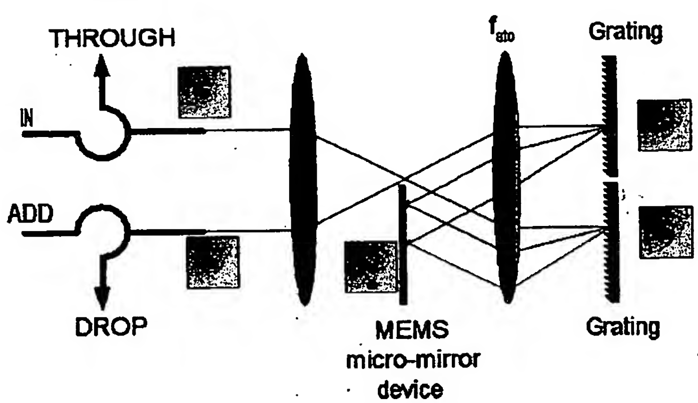
In this embodiment, we make a minor modification to the above Demuxed COADM, where there is no 'Add' and 'Drop' ports. Here, the grating is used to disperse the light angularly from the muxed inputs through the ATO lens, where each wavelength channel falls on an individually controllable MEMS analog tiltable mirror. The attenuation is adjusted by varying the offset of the returning beam to the circulator fiber. The mirror need only tilt in 1 dimension. The returning beams once again hit the grating, and are sent out via the 'Through' port. It should be noted that in this embodiment, the beam size on either side of the ATO lens need not be the same.
Note that this is a flat-top design. Also note that if the MEMS mirrors are pitched tightly and that each cover a 2nm wavelength spread (or tighter), this device also operates as a Dynamic Gain Equalizer. Note that this device can also operate as a channel blocker with a bistable micromirror.



Muxed DCE (Flat-Top)

Muxed COADM (Flat-Top)

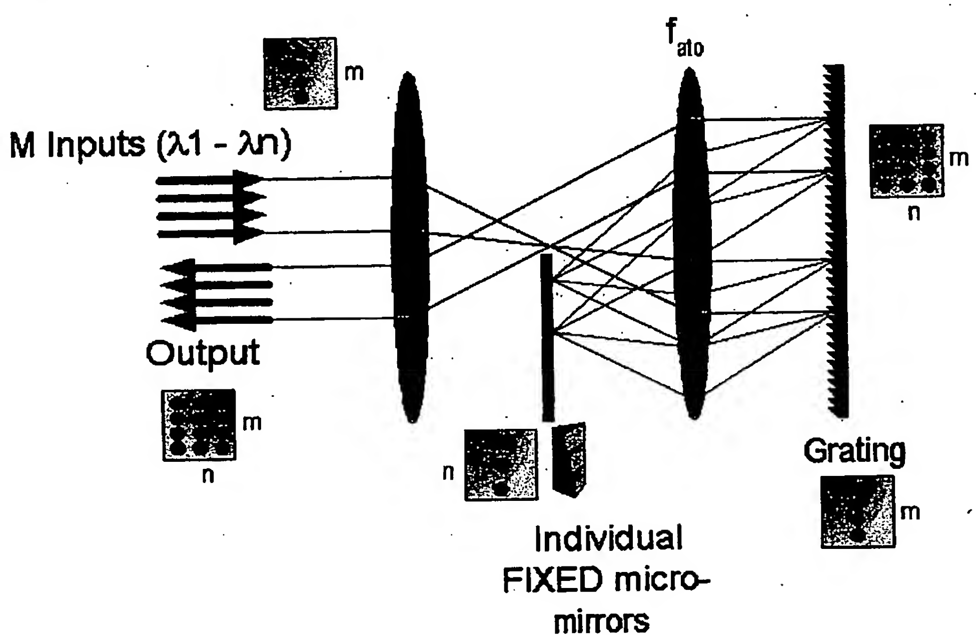
In a variant of the above Muxed DCE, a second grating is placed at the back focal plane of the ATO lens. The MEMS mirrors are bi-stable where the beams are either retro-reflected along its input path, and out via the 'Through' port, or switched to the second grating (or a different spot on the original grating) such that the different wavelengths are muxed once again on their way out the 'Drop' port. At this time, it is possible to send light down the 'Add' port to be sent out the 'Through' port.
Note that here too, as in the above Muxed DCE embodiment, the beam size at the grating need not be the same at the front and back focal planes of the ATO lens.
Note that this is a flat-top design.



Muxed COADM (Flat-Top)

Multi-Fiber Demultiplexer (Flat-Top)

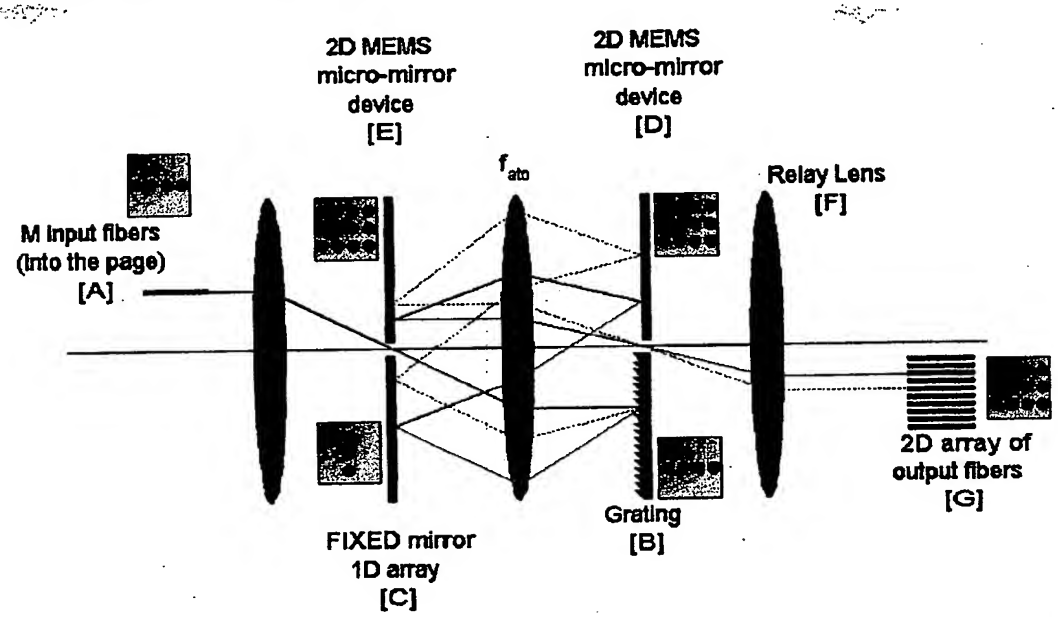
The Flat-Top Demux shown earlier can be used with multiple (M) fiber inputs each carrying N wavelength channels as shown below.



Multi-Fiber Demux (Flat-Top)

Demuxed Wavelength Switch (not Flat-Top)

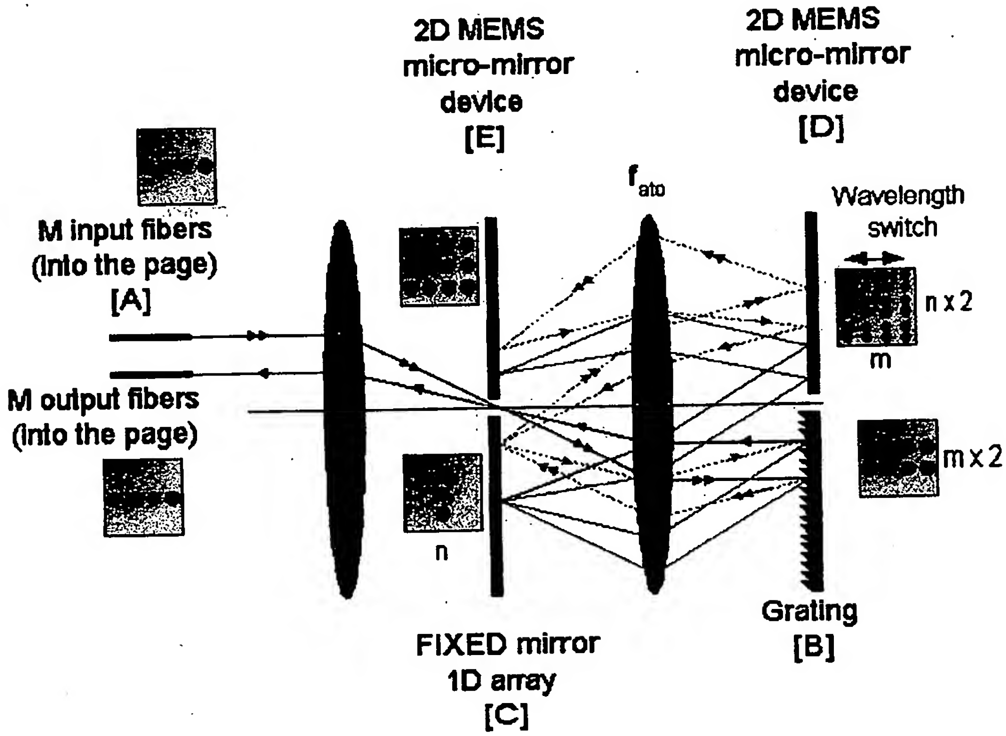
Full wavelength switching functionality requires the control to place ANY wavelength channel from ANY input fiber to ANY output fiber. The M muxed inputs are (in this embodiment) located in a line (component [A] below). These beams are relayed to a FIXED linear array of reflectors [C] (necessarily of different deflection angles). Note that the all the light from the M inputs of a given wavelength collapse to a point at [C]. These beams are redirected by the fixed mirrors [C] to a 2-D array of 2-D tiltable MEMS mirrors [D] at the back focal plane of the ATO lens. These mirrors at [D] are analog controlled and can steer the beams to any one of another mirror on a 2-D array of 2-D tiltable MEMS mirrors [E] located at the front focal plane of the ATO lens.These micro-mirrors at [E] direct the beams to be parallel to the optical axis which are sent out the gap between the grating and the MEMS chip [D], through the relay lens [F], and finally to the desired fiber in the 2-D array of output fibers at [G].
Note that this is not a flat top design.



Demuxed Wavelength Switch (not Flat-Top)

Muxed Wavelength Switch (Flat-Top)

This embodiment describes how to take one of N wavelength channels from one of M input fibers and place it on any one of M output fibers. Because of the double pass off of the grating, this is a flat-top design. Note that the inputs for the blue channel are marked with a DOUBLE arrow head, and on the way out to the output fibers, a SINGLE arrow head is used.

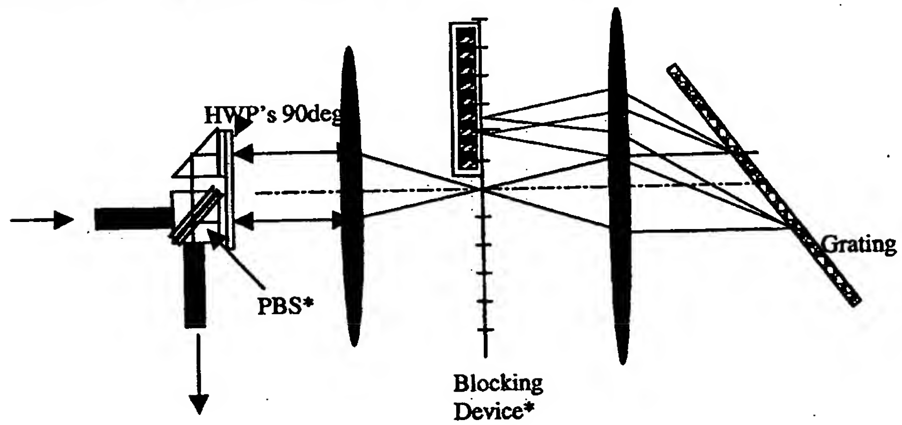


Muxed Wavelength Switch (Flat Top)

Note that the same M fibers can be used for both inputs and ouptuts by using a circulator on each port.

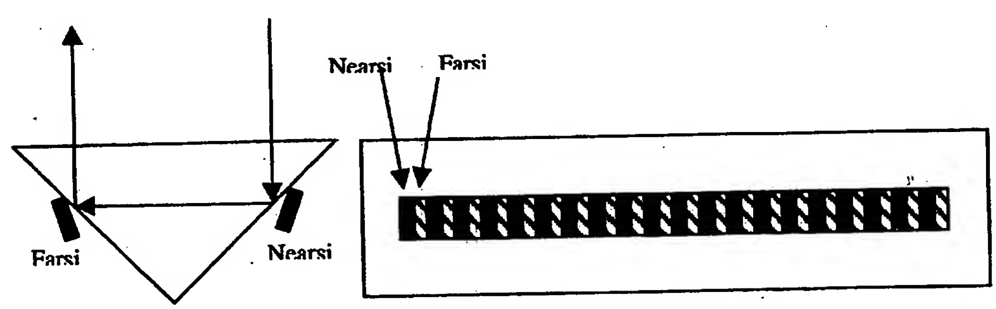
Muxed Wavelength Channel Blocker

Here are some thoughts about the blocker device. First, we can eliminate any need for a circulator by using a polarisation "Sagnac" device as I discussed earlier, using an extra 90 degree rotation on both paths as shown to bias the loop into the through condition (it would normally be in the reflection condition and need the circulator.. The polarisation diversity is handled by directional diversity in this setup.



The angles-to-offsets property of the lenses means that after reflection off the blocking device the light from each port returns to the other port for all wavelengths. The nice feature of this arrangement is that the performance of the beamsplitter is not critical provided that the blocker portion actually blocks the light, (rather than rotating its polarisation as I suggested for switching). The isolation of the blocker device sets the performance, whereas with polarisation rotation the isolation would be set by the PBS at about 25 dB. There is a way to use a double stage PBS, but it's better wthout.

The ideal device for spectral blocking is a continuous reflector, with some way of destroying the reflection in selected regions. We can achieve this exactly by using total internal reflection with switches behind the reflector to frustrate the reflection in the appropriate region. For example, Optical Switch Corp developed switches that do this. We need arrays of something like that. The TIR device would be made as a 90 degree reflector orthogonal to the paper as drawn, and would act like a mirror in the plane of the paper as shown above, preserving the loop setup in the spectrometer.. If we can tolerate the required depth of focus, we could use alternate the devices (wit appropriate offset) on the two TIR surfaces to provide a little working space between devices. There are probably many other ways to kill TIR from the back. Details left for later.



Ian

c) Describe the prior art

Currently Dynamic Gain Equalizer, Dynamic Channel Equalizer and COADM functionality require complex opto-mechanical layouts, (where the optical elements are not located on a single axis), to achieve the spatial separation needed to perform the desired function. This results in systems which are rather large in comparison to the layouts presented in this disclosure.

For details in the prior art for demux, DGE's, DCE's, COADM's, look at earlier disclosures under these device names.

d) Identify what aspects of the invention need to be protected. Remember that the purpose of a patent is to PREVENT OTHERS from doing something.
This disclosure is protecting the use of the ATO concept for any wavelength functionality, and to note the versatility of the In-Line ATO optical platform for many applications.

e) What is the status of the invention at JDSU? (May range from "in production" to "concept only")
Concept only

D:Manager's Comments

E. Dated in Nepean, Ontario, Canada this ________day of _______ 199__

________________	Rajiv Iyer
Signature of Originator	**Print name**
Read and understood by:	________________
	Witness
________________	________________
Signture of witness	**Date**